CONCEPT PAPER

DEFINING WETLAND WATER REQUIREMENTS AND EVAPORATION RATES RELATIVE TO THE LAHONTAN VALLEY

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May, 1995

Introduction

The purpose of this paper is to define the water requirements or demand for three different wetland habitats and the conceptual water regimes associated with each habitat. In order to define the volume of water needed to sustain wetland habitat, a number of factors such as evaporation, evapotranspiration, soil moisture depletion, percolation, and precipitation are used to determine and calculated a wetlands water budget. Generally, water requirements or water budgets for wetlands management rely on a hydrologic balance where inflow equals or exceeds losses. Evaporation and consumptive use by vegetation result in the greatest water loss from wetlands. The key factors controlling evaporative and consumptive use losses are temperature, hours of daylight, and wind speed.

Water requirements for Great Basin wetlands vary depending on the desired mix of habitats. The Stillwater marshes historically had a mix or gradation of perennial, ephemeral emergent and playa wetlands. Historically, Carson Lake was a shallow lake that provided perennial marsh habitat, but since the creation of the Newlands Irrigation Project both Stillwater and Carson Lake have been sustained by irrigation drainwater and have become an ephemeral emergent marsh habitat. In this analysis certain wetland habitat conditions will provide a baseline for water requirement calculations, but this paper is not intended nor does it represent a wetland management plan for Stillwater National Wildlife Refuge or Carson Lake.

Evaporation Rates

There are a number of factors affecting the evaporative process (Bensen, 1986), including the difference between air and surface temperatures, type of clouds, degree of cloudiness, solar irradiation, and relative humidity. These factors do not vary significantly throughout the Lahontan Valley except the air to surface temperature difference and to a lesser extent relative humidity.

The pan evaporation data collected at the Fallon Agriculture Field Station near the geographic center of the Newlands Irrigation Project offers the only long term record of evaporation for the Lahontan Valley. Records from the Agriculture Field Station show an average annual evaporation rate of 60.6 inches/year for the period between 1940 and 1993 (Table 1). An earlier report prepared by the Fish and Wildlife Service (June, 1964) cites pan evaporation data at the Agriculture Field Station to average 54.88 inches/year for the period between 1906 and 1964 (Table 1). In that study, pan evaporation rates were adjusted by a 0.94 coefficient to reflect studies done in California which showed the actual evaporation rates from large bodies of water are less than what was recorded from pan evaporation measurements (U.S. Fish and Wildlife Service, 1964). After the reduction coefficient is applied to pan evaporation rates, the mean annual evaporation rate is calculated to be 51.58 inches/year.

Reasons for the variation between average annual evaporation rates for the different periods of record are unclear and could be numerous. These differences could result from changes in data collection procedures, different equipment and methodology, or changes over time in the factors effecting evaporation at that site. Since information is unavailable to determine what factors may have affected the variation of data for the different periods, there is a range of 51.58 to 60.09 inches/year of annual evaporation, on average, for the Fallon Agriculture Field Station.

Evaporation rates associated with wetland areas at the Stillwater National Wildlife Refuge (Stillwater NWR) and Carson Lake are expected to be different than the Fallon Agriculture Field Station reading due to differences between the air and surface temperature differential and relative humidity. Wetland surfaces are cooler because soils are moist or covered by water. Additionally, the wetlands are subject to dry winds from the bordering open desert lands. Both of these factors would cause evaporation rates at the wetlands to differ from the Fallon Agriculture Station. For these reasons, pan evaporative measurements have been made at Stillwater NWR and Carson Lake since 1993. Data from these sites (Table 2) show a marked increase in evaporation rates (25% - 95%) during the months of June, July, and August, but is lower in the early spring and fall months. These limited measurements suggest a slightly higher evaporation rate for Lahontan Valley wetlands, but there is insufficient data to warrant adjusting the long-term mean annual evaporation rate of the Fallon Agriculture Field Station in water requirement calculations for the Lahontan Valley wetlands.

For the purposes of calculating water requirements for Lahontan Valley wetlands in this report, a value of 55 inches/year was chosen to represent evaporative losses. In order to calculate specific water requirements for the hypothetical hydrologic regimes associated with the three different wetland habitats the monthly averages depicted for the period of record between 1940 and 1993 in Table 1 will be used.

Evapotranspiration

Evapotranspiration, simply stated, is the combination of evaporation and consumptive water use by plants. In most locations, as with the Lahontan Valley, pan evaporation data is often readily available. There are a number of studies and methods developed to relate evaporation or climatic data to evapotranspiration. The most well known is the Blaney-Criddle formula but other formulas developed by Christiansen (1960 and 1966) and Grassi (1964) are based on studies conducted in the early 1960s in Utah and are more representative of conditions in the Great Basin.

Studies have shown (Christiansen and Low, 1970) that in desert climates (southern New Mexico and Mohave Desert), annual evapotranspiration rates exceed evaporation rates by as much as three to one in small study plots. A ratio of 1.02 to 1.54 is more representative of larger wetland areas (ibid). The size and vegetative composition of the wetlands also affects the rate of evapotranspiration. The maximum or "potential" evapotranspiration rate of a plant occurs when soil moisture and leaf surface area are not limiting factors, whereas actual evapotranspiration is controlled more by climatic factors (ibid). Studies conducted on wetlands in Utah near the Great Salt Lake show the ratio of evapotranspiration to evaporation are greater for cattails than salt grass (ibid).

The U.S. Fish and Wildlife Service report of water requirements for the Stillwater NWR (June, 1964) used the Blaney and Criddle formula to calculate annual evapotranspiration rates based on monthly averages. This report calculated the evapotranspiration rate at 50.86 inches/year for emergent marsh vegetation and 24.48 inches/year for salt grass pasture. Information from the Utah studies (Christiansen and Low, 1970) suggests that wetlands which include bulrush and cattails would have evapotranspiration rates that are higher than the evaporation rate. To adjust the evapotranspiration rates to reflect other wetland vegetation such as alkali bulrush, hardstem bulrush, spike rush, widgeon grass, etc., use of a 1.25 multiplier[1] on the mean annual evaporation rate would show the evapotranspiration rate for some Lahontan Valley wetland habitat to be about 68.75 inches/year (55 in/yr X 1.25 = 68.75 in/yr).

Precipitation

Precipitation in the Lahontan Valley ranges from 8 inches/year for lands above 5,000 feet in elevation to 4 inches/year in the Carson Sink which is about 3,850 feet in elevation (California Department of Water Resources, 1991). The average annual precipitation data from the Fallon Agriculture Station, located near the City of Fallon, is 4.95 inches/year.

Based on this information, it can be assumed that, on average, about 4 to 5 inches/year fall on the Lahontan Valley wetland areas. In calculating the water requirements for the Lahontan Valley wetlands, 5 inches/year of precipitation will be used as the annual average total precipitation figure. Due to the sandy soils and relatively flat topography, little or no runoff occurs from the upland sand dune areas into the adjacent wetlands. Total annual precipitation rates can be factored into the evaporation rates to determine net water loss from the wetlands. Both of the evapotranspiration formulas cited above include precipitation gains in the calculation of "potential" evapotranspiration.

Groundwater Percolation

The volume of wetland water that percolates into the groundwater can be assumed to be minimal under average hydrologic conditions. However, in drought years or when ephemeral wetlands are recharged with water after drying out, there is the potential for some volume of inflow to be lost due to seepage or soil moisture replenishment.

U.S. Geological Survey groundwater modelling (Maurer and others, 1994) shows that the wetland areas at Stillwater NWR and Carson Lake are groundwater discharge zones, meaning groundwater moves upward from the aquifers towards the surface and under certain conditions evaporates into the atmosphere. From this report it can be assumed that only minimal water losses occur due to percolation and that the seepage that does occur at the wetlands is not a source of supply (recharge) to Lahontan Valley aquifers.

The seepage losses associated with filling dry marshes can be estimated using seepage rates recorded by the Bureau of Reclamation from ponding studies done on various Newlands Irrigation Project canals. In the Lahontan Valley wetlands, these seepage losses are only expected to occur for a short period of time during the initial inflow stages of water delivery. The wetland soils are generally fine-textured clays or are underlain by shallow impermeable soil layers that would reach saturation soon after water is applied. While these losses could be about 6 inches/day based on Reclamation's recorded seepage rates for Newlands Irrigation Project canals near Stillwater NWR (Bureau of Reclamation, 1993) such losses would most likely last for a few days until wetland soils became saturated.

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[1] Christiansen and Low (1970) define this multiplier or ratio between evaporation and evapotranspiration as varying from 1.00 to 1.92 between June and October for New Mexico desert wetlands, while other desert wetlands in Utah had ratios of 1.13, 1.28, 1.33, 1.47, and 1.54. The choice of 1.25 as the multiplier for Lahontan Valley wetlands is an assumption made that represents a value close to the median value of these other desert wetland ratios.

Water Requirements

Water requirements or the water demand for wetlands vary depending on the type of wetland habitat to be sustained. Lahontan Valley wetlands include a range of wetland habitats from ephemeral playa (mudflats) to perennial marshes, all with different water requirements. In order to calculate annual water requirements for the different wetland habitats, factors such as evaporation or evapotranspiration, precipitation, and seepage must be considered along with the depth of standing water in the wetland and the length of inundation. General water requirements are calculated for three representative wetland habitats in order to more accurately define the total overall water requirements for the primary wetland habitat areas in Lahontan Valley.

The following representative habitat types define conceptual water requirements that are generally representative of the primary wetland habitats that the U.S. Fish and Wildlife Service, Nevada Division of Wildlife, and other environmental or wildlife conservation groups would consider in more detailed wetlands management planning. In the development of wetland management plans the distinction between the three may not be as definitive as is portrayed in water requirement calculations below.

Ephemeral Playa

This wetland habitat generally has from 12 inches to as little as 1 inch of standing water for 9 to 10 months a year. Water delivery or inflow to this habitat type could begin in the fall and continue into early winter as a possible management scenario and will be used as a hypothetical scenario for the purposes of calculating water requirements associated with an ephemeral playa wetland habitat in this paper. Maximum water depth would be about 12 to 15 inches during the inflow period declining during the remainder of season until the playa goes dry in late spring. The major water loss to this habitat type would be evaporation since the vegetation associated with these ephemeral playa wetlands is not predominant or physically large enough to have an evapotranspiration rate that is greater than evaporation.

Based on the lower evaporation rates of fall, winter, and spring (Table 1) the cumulative evaporative losses would be about 34 inches. Precipitation during this same period averages about 4 inches. The calculation of water demand for the ephemeral playa habitat would entail about 2.7 acre-feet per acre (ac-ft/ac) of surface water inflow coupled with 4 inches of precipitation (.33 ac-ft/ac) for a total wetland inflow of 3.03 ac-ft/ac/yr. Evaporation would account for about 2.8 ac-ft/ac of the playa wetland losses for the nine month period and seepage or soil moisture replenishment could account for another 10 percent of the wetland water loss for a total wetland loss of about 3 ac-ft/ac/yr. Under this hypothetical hydrologic regime the playa wetland would sustain water levels of 12 inches to 1 inch over a nine to ten month period of each year.

Ephemeral Emergent Marsh

This wetland habitat generally requires from 2 feet to as little as 2 inches of standing water during the growing season which is from April or May until October each year. This wetland habitat could go dry for one to three months each year and continue to sustain emergent wetland vegetation.

Because this wetland habitat is dominated by vegetation, evapotranspiration accounts for the major water loss. The vegetation associated with this habitat range from marsh grasses or rush to alkali bulrush and cattails. Based on the vegetation composition, the 1.25 multiplier for evaporative losses is applicable to calculate the evapotranspiration losses during the periods of inundation.

Using evaporation rates (Table 1) for May through October (the months when peak evaporation occurs), the cumulative evapotranspiration is calculated to be about 55.25 inches for that period each year. Surface water inflow would be required in April or May and continue throughout the growing season each year. If surface inflow is curtailed, this wetland habitat would eventually go dry each year. In some years, depending on surface water inflow volumes, this could occur in August or September when the peak evaporation occurs or could be sustained into the winter until the wetland goes dry. To maintain, on average, a water level about 12 inches through most of the summer and offset evapotranspiration losses about 6 ac-ft/ac of total surface water inflow would have to occur during the growing season. The surface water inflow coupled with the 0.12 ac-ft/ac of precipitation that occurs on average during this period would provide a total of about 6.1 ac-ft/ac. Seepage losses for this wetland habitat type are considered to be almost negligible since the dry period is during the winter when soils are not subject to the high evaporative rates of the summer that affect the playa wetlands[2].

Perennial Marsh

This wetland habitat would have standing water (4 to 2 feet deep) throughout the year. Water depths can vary in a palustrine wetland from 6 feet to as little as 6 inches and sustain perennial wetland vegetation. This wetland habitat would not go dry except in years of extreme drought or for management considerations. This representative wetland habitat could be characterized by about 50 to 70 percent open water and not less than 30 percent emergent vegetation. The open water portions of a perennial marsh should sustain submergent vegetation (e.g., sago and other pond weeds).

Evaporation would affect the open water portions of this perennial wetland habitat while evapotranspiration would account for the water loss on the areas of the habitat dominated by emergent vegetation. Seepage losses would not be expected to be a factor in calculating wetland water loss since the soils would be continually saturated. The emergent vegetation could consist of mostly alkali bulrush and cattails. Using such a vegetation composition for example, the 1.25 multiplier to evaporative losses would be applicable to calculate the evapotranspiration losses on the vegetated portions of a perennial wetland.

Total wetland losses would be based on an annual evaporation rate of 55 inches/year and a calculated evapotranspiration rate of 68.75 inches/year. For example, using a perennial wetland made up of 50 percent emergent vegetation and 50 percent open water, a weighted average of 61.8 inches/year of evaporative and consumptive use losses would be expected for this type of wetland habitat.

To sustain an average water depth of 24 inches throughout the year the total water requirements for perennial marshes in Lahontan Valley is about 7.1 ac-ft/ac/year. This is based on surface water inflow of about 6.75 ac-ft/ac/year coupled with 5 inches of total precipitation (0.42 ac-ft/ac/year). The water requirements for a perennial marsh that was

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[2] Calculations: Total wetland inflow (surface water plus precipitation) of 6.1 ac-ft/ac/year (6 ac-ft/ac + 0.12 ac-ft/ac) - total wetland losses (evapotranspiration + seepage loss) of 4.66 ac-ft/ac/year (4.6 ac-ft/ac + (1% x 6.1 ac-ft/ac) = 1.44 ac-ft/ac/year or about 12 inches of standing water over one acre of wetland on average.

maintained at an average depth of 3 feet throughout the year would be about 8.1 ac-ft/ac/year.

These annual water requirement calculations for the example perennial wetland habitat assume that there would be little or no carry over of water from year to year. Under actual wetland management conditions, this would not be truly representative of the long-term annual water requirements. Recognizing that wetland managers may also desire to sustain water varying water depths rather than an average of 2 feet, using a figure of 7 ac-ft/ac/year as the water requirement to characterize varying perennial wetland water depths seems to provide a representative value to calculate total wetland water requirements.

The hydrologic regimes calculated for the three hypothetical wetland habitats are representative of the wetland habitat that could be maintained in Lahontan Valley. An average Lahontan Valley wetland water demand can be calculated using an average for the three hydrologic regimes assuming that the entire wetland area would be comprised of one-third ephemeral playa, one-third ephemeral emergent marsh, and one-third perennial marsh. The average surface water inflow requirements for Lahontan Valley wetlands would be about 5.1 ac-ft/ac/year.

Summary

The above calculations to determine average surface water requirements are for planning purposes and are not intended to represent actual Lahontan Valley wetlands management plans or practices. These calculations were developed to serve as a conceptual evaluation of a possible water budget for Great Basin wetland habitat in Lahontan Valley. The 5.1 ac-ft/ac/year average does not take into account the full range of wetland management options necessary to sustain productive wetland habitat over a long period of time under varying hydrologic conditions (e.g. drought and flooding). Additionally, wetland management must include provisions to restore and maintain natural biodiversity, mitigate drainwater quality problems, prevent avian disease outbreaks, or flush accumulations of salts and trace elements that occur in these terminal wetlands. The average surface water requirement calculated above does not provide any surface water to mitigate avian disease control or to flush perennial and to a lesser extent ephemeral emergent wetland habitats of accumulated salts and trace elements. This would require additional surface inflows that are not reflected in the 5.1 ac-ft/ac/year surface inflow average calculated to offset only evaporative, evapotranspiration, and seepage losses.

Surface water requirements for Lahontan Valley wetlands would also change based on the desired mix of wetland habitats. For example, if emphasis was placed on providing a greater percentage of ephemeral playa wetlands the average surface water demand would be lower (e.g., 50 percent playa, 30 percent emergent, 20 percent perennial, the average surface water requirement would be about 4.5 ac-ft/ac/year). On the other hand, if the management emphasis was to provide a greater percentage of ephemeral emergent and perennial wetlands with little ephemeral playa the average surface water demand would be greater (e.g., 10 percent playa, 40 percent emergent, 50 percent perennial, the average surface water demand would be about 6 ac-ft/ac/year).

For the purposes of determining a representative wetland water demand for management planning relative to the Lahontan Valley Wetland Water Rights Acquisition program proposed by the U.S. Fish and Wildlife Service, it is reasonable to use a figure of 5 ac-ft/ac/year as an annual average to calculate surface water requirements. This recognizes that more comprehensive wetland management planning may increase or decrease the average surface water requirements for Lahontan Valley wetlands.

TABLE 1
PAN EVAPORATION

Fallon Agriculture Station, 1906 - 1964

Months	1906 - 1964 Pan Evaporation (inches)	1940-1993 Pan Evaporation (inches)	Precipitation (inches)
January	0.96	1.18	0.60
February	1.72	2.02	0.59
March	3.66	4.33	0.49
April	5.37	6.08	0.44
May	6.97	7.61	0.57
June	7.99	8.59	0.33
July	8.85	9.63	0.16
August	7.94	8.35	0.16
September	5.47	5.88	0.24
October	3.45	3.96	0.45
November	1.62	1.96	0.33
December	0.88	1.01	0.59
Total	54.88	60.60	4.95

Source: Fallon Agriculture Field Station records and the U.S. Fish and Wildlife Service, Report on the Water Requirements and Water Use of the Stillwater National Wildlife Refuge and Management Area, Nevada. June, 1964.

TABLE 2
COMPARISON OF WETLAND AND FALLON AGRICULTURE STATION PAN EVAPORATION DATA
(1993 and 1994)

1993 Pan Evaporation Data

Months	Ag. Station Pan Evap. 1940-1993 (inches)	Ag. Station Pan Evap. 1993 (inches)	Stillwater Pan Evap. 1993 (inches)	Carson Lake Pan Evap. 1993 (inches)
January	n/a	n/a	n/a	n/a
February	n/a	n/a	n/a	n/a
March	4.33	n/a	n/a	n/a
April	6.08	n/a	n/a	n/a
May	7.61	8.78	10.95	11.99
June	8.59	7.58	6.61	8.56
July	9.63	10.52	12.95	13.45
August	8.35	10.68	10.21	9.12
September	5.88	6.58	5.28	6.87
October	3.96	2.09	2.52	1.93
November	n/a	n/a	n/a	n/a
December	n/a	n/a	n/a	n/a
Total	54.43	46.23	48.52	51.92

1994 Pan Evaporation Data

Months	Ag. Station Pan Evap. 1940-1990 (inches)	Ag. Station Pan Evap. 1994 (inches)	Stillwater Pan Evap. 1994 (inches)	Carson Lake Pan Evap. 1994 (inches)
January	n/a	n/a	n/a	n/a
February	n/a	n/a	n/a	n/a
March	4.33	5.52	2.79	2.56
April	6.08	6.31	4.45	4.10
May	7.61	7.73	6.75	6.64
June	8.59	10.32	9.88	10.75
July	9.63	10.37	18.61	20.32
August	8.35	11.98	13.52	14.28
September	5.88	7.98	8.16	8.70
October	3.96	4.23	3.95	3.54
November	n/a	n/a	n/a	n/a
December	n/a	n/a	n/a	n/a
Total	54.43	64.44	68.11	70.89

Source: U.S. Fish and Wildlife Service field data and Fallon Agricultural Station annual reports

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